Editorial: Scour in the marine environment

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1. Introduction

Scour associated with anthropogenic activities in the marine environment has continued to be of importance due to our continued and growing global sea trade, and our exploration and exploitation of marine resources. Indeed, research into scour development associated with the placement of foundation structures, pipelines and cables or the movement of vessels in the marine environment is not a new area of study and a significant amount of knowledge has been gained over the years in this subject. Numerous studies have been undertaken for the offshore oil and gas industry, although despite the rapid growth in the oil and gas industry in the 1970's the level of knowledge and data obtained from these developments has not always been openly available either due to commercial sensitivity or because there was no formal structure for capturing the results of any monitoring undertaken.

The continued expansion of port facilities and advances in ship design and larger vessels have resulted in a requirement to assess further the impact of vessels on the stability of port structures as well as the requirement of navigation and sea defence structures to protect coastal areas and port facilities from the dynamic and energetic environments in which they are situated under a changing climate. Over the last decade the drive for developing offshore renewable resources (wind, waves, tides) has led to specific requirements for scour hazard assessment relating to the associated foundation structures and the cabling necessary for in-field transmission and power export. These developments have also been key in driving further research into obtaining a greater understanding of the scour processes associated with placing structures in the coast and offshore regions.

In 2005 in the UK, a research advisory group (RAG) was established by the Department for Trade and Industry (DTI)

to consider research priorities in relation to the potential environmental impacts of offshore wind farm (OWF) developments and their impacts on other users of the sea. This was corresponding to the first round of commercial OWF projects in the UK (round 1) and the recognised need for additional research to inform the consenting process for the second round of commercial OWF development (round 2). Three priority research projects were taken forward

- review of round 1 sediment process monitoring data – lessons learnt (SED01)
- dynamics of scour pits and scour protection (SED02)
- review of channel migration (SED06).

The aim of SED01 was to draw together the sediment process monitoring work carried out on round 1 OWF developments and review the methods, data, results and impacts in order to identify lessons learnt and to provide relevant recommendations for monitoring of round 2 developments (DECC, 2008a) while establishing an accessible evidence base. SED02 dealt specifically with those aspects of sediment monitoring related to scouring around wind turbine foundations (DECC, 2008b) with the aim of examining scour patterns and identifying lessons learnt. A further study, covering both SED01 and SED02 topics, was reported on by COWRIE (2010), drawing upon available new data at OWF sites in UK and European waters.

2. Scour and scour hazard assessment

Scour is a physical process related to the movement of the seabed sediment as a result of the flow of water away from a structure. The soil conditions are described by geotechnical parameters, therefore scour is of a geotechnical nature as it relates to the reduction in ground level around a structure.

A scour hazard assessment may be performed at a range of levels, which in its most simplistic form could consist of an analysis of seabed features such as bedforms to identify seabed mobility in sands or identifying erosion in the case of clay soils (Whitehouse *et al.*, 2010). In environments where the seabed is mobile under the prevailing hydrodynamic conditions, it is inferred that the installation of a structure on the seabed may result in scour occurring (Whitehouse, 1998). Extending the analysis to include information on the known characteristics of the hydrodynamic conditions (currents and waves) combined with knowledge on the soil and assessing its mobility provides an understanding of the conditions under which the soil is mobile, and this can feed directly into the scour assessment methodology.

3. Marine soils

A significant amount of research has been conducted into scour in uniform sandy soils over many decades and numerous methods have been proposed to estimate scouring in such non-cohesive soils. Summaries of many of these studies are presented by Herbich (1981), Herbich *et al.* (1984), Breusers and Raudkivi (1991), Hoffmans and Verheij (1997), Whitehouse (1998), Melville and Coleman (2000) and Sumer and Fredsøe (2002). Much of the work presented by Herbich (1981) and Herbich *et al.* (1984) was based on empirical type design rules since many of the hydrodynamic processes were still poorly understood.

However, comparatively few scour studies have been undertaken using real marine soils, which are often variable in their make up. Seabed sediments are often made up of some combination of silts, clays, sands and gravels, which do not respond in the same way as uniform sands. Their resistance to erosion and rate of erosion is still an area of uncertainty and requires further examination so that a clearer understanding of scour for multi-modal sediment distributions can be achieved. Therefore, it will be informative, for example, to study further the role of unconsolidated fine sediments in scour evolution. There is uncertainty in the scour response of clays. Their erosion rate due to hydraulic forces, abrasion through transport of granular sediments and ‘weathering’ of the exposed surface on the seabed also requires further examination to determine the controlling mechanisms and the long-term progressive scour response.

The prediction of scour in cohesive or multi-modal soils is more complex. Typically the scour process is much slower; as a result the effect of scour is very much dependent on the period of time that the structure will remain at the site. An assessment of the scour depth in cohesive soils can be made using various methods, of which the approach first described by Briaud *et al.* (1999) is one of the more established. Their method combines an empirical formula with an assessment of the rate of scour

development based on site-specific testing of the erosion function, which allows for the incorporation of the soil behaviour directly into the predictions. Such methods may allow the approach to be extended to non-cohesive soils also.

Annandale (1995) proposed an approach to estimating the erosion potential of real soils through the use of the stream power parameter, P , and its relationship to the ability of the soil to resist scour, defined through an erodibility index, K . The erodibility index provides a measure of the in situ strength of the material. The approach allows for the physical properties of the soil to be considered and, although the method does not directly take into account the chemical properties of the material, it includes a mass strength number, which represents the relative influence of chemical bonding properties of the soil through the unconfined compressive strength. The stream power provides a measure of the rate of energy dissipation in the near-bed region due to hydrodynamic forces expressed by the following relationship.

$$1. \quad P = f(K)$$

where P is a function of K . If P exceeds the erosion threshold then scouring will occur. The approach was originally developed for scouring of rock spillways, but the methodology applies equally to marine type soils (e.g. Annandale, 2006). Harris *et al.* (2010) adapted the method of Annandale for marine soils and demonstrated its application to offshore foundations.

For scour assessments in general, it is very important to know the characteristics of the surficial soil, and data analysis starting from 1 m below the seabed or deeper in a foundation site investigation will not always be representative of the surface sediment properties required for a scour assessment. Knowledge of the sediment properties below this surficial layer will become important, though, for predicting scour development with depth into the seabed should scouring extend beyond the surficial sediment layer.

4. Challenges

There are three distinct but related areas in which further research will lead to benefits in understanding and predicting scour response. The first relates to the scour potential and scour development with time in marine soils (gravel–sand–silt–clay mixtures); the second relates to scour response around complex foundation structures (gravity base, jacket and multi-leg foundations); and the third relates to the optimisation of scour protection performance.

The present themed issue of *Maritime Engineering* presents a collection of four papers that will address some of these challenges and present the outcomes from studies that are

helping to obtain a better understanding of the overall scour process. The paper by Whitehouse *et al.* (2011) covers scour development around gravity base foundations, the behaviour of scour predictions and scour protection performance. This work is proposed within a scour management framework, which could have wider applicability.

The paper by Nielsen *et al.* (2011) concentrates on scour protection stability at foundations and provides specific insight into the processes by which rock layers can settle into the seabed. Some charts are presented to help the design process and applied to a case example from the field.

Myrhaug and Rue (2003) presented an approach to predict the scour depth and width around a fixed pipeline as well as the scour depth around a vertical cylinder in random waves using a stochastic approach. Myrhaug and Ong (2011) have extended this stochastic approach to provide a means of predicting the maximum scour depth and maximum scour width below pipelines exposed to both long-crested and short-crested nonlinear random waves. Such an approach can be extended to include scour development around cables.

In the marine environment jet-related scour can be associated with discharges from outfalls or vessel movement. The paper by Hoffmans and Verheij (2011) presents an overview of the state of knowledge on jet scour, based around current practice within the Netherlands. Jet scour has received more close attention in recent years due to the development of high-speed vessels and the interaction of their propulsion systems with port structures either during manoeuvring or while moored. In addition, the requirement for energy and the replacement of power stations having cooling water requirements necessitates an assessment of the stability of intake and outfall facilities on the seabed and other environments.

It is hoped that this themed issue will have a broad appeal as scour has increasingly frequent relevance given the drive to utilise marine resources and the general increase in maritime global trade. The guest editors are extremely grateful to the various authors for their contributions to the issue.

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